Thermo-hydrodynamic instabilities in a high aspect ratio Couette-Taylor system using Direct Numerical Simulation

S. Poncet, S. Viazzo *

The influence of a radial temperature gradient on the stability of Couette-Taylor flow has been investigated by direct numerical simulation. The cavity is characterized by a narrow gap $\eta = R_i/R_o = 0.8$ and a high aspect ratio $\Gamma = H/(R_o - R_i) = 80$, R_i and R_o being the radii of the inner and outer cylinders and H their height. The flow depends on two physical parameters: the Taylor number $Ta = \Omega R_i d/\nu (d/R_i)^{1/2}$ and the Rayleigh number $Ra = \alpha \Delta T d^3/(\nu\kappa)$, with $d = R_o - R_i$ and Ω the rotation rate of the inner cylinder. 15 cases have been computed for $Ta = [11 - 150]$ and $Ra = [1166 - 13228]$ to enable comparisons with the experiments of Guillerm [1].

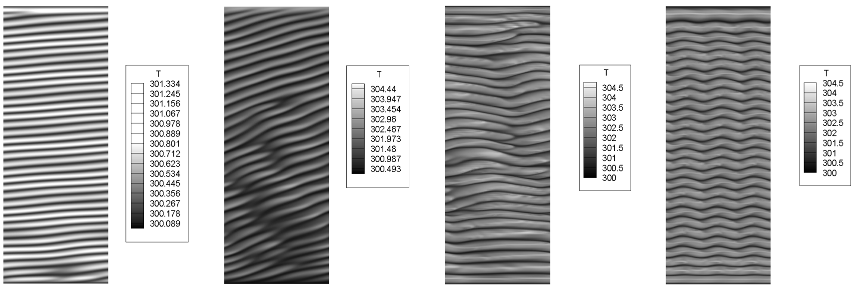
The numerical method is based on the 2D compact fourth-order projection decomposition method of Abide and Viazzo[2], extended to cylindrical coordinates on non-staggered grids. The time advancement is second-order accurate. The derivatives are approximated using fourth-order compact formula in the radial and axial directions and Fourier series in the azimuthal direction. Due to the large aspect ratio, the domain is axially decomposed into 8 subdomains using the influence matrix technique. The thermal effects are considered using the Boussinesq approximation.

The aim of this work is to characterize all the flow patterns occuring in the system for various Rayleigh and Taylor numbers. At low Ra, the first instability appears in the form of regular spirals (Fig.1a). For higher values of Ra, dislocations may occur (Fig.1b) and when one increases Ta, spirals coexist with a wavy vortex flow (Fig.1c) and finally only the wavy vortex flow subsists at high Ta (Fig.1d). The spatiotemporal properties of these patterns have been fully determined and compared to the work of Guillerm[1].

*Laboratoire M2P2 UMR 7340 CNRS - Aix-Marseille Université, Marseille, France

[1]Guillerm, *PhD thesis*, Université du Havre (2010)

[2]Abide and Viazzo, *J. Comp. Phys.* **206**, 252-276 (2005)



(a) (b) (c) (d)

Figure 1: Temperature maps at $(r-R_i)/d = 0.8$ in the (θ, z) plane for: (a) $Ra = 2063$, $Ta = 50$, (b) $Ra = 7150$, $Ta = 40$, (c) $Ra = 7150$, $Ta = 75$, (d) $Ra = 7150$, $Ta = 120$. $61 \times 64 \times 488$ mesh points are used in the (r, θ, z) directions with $\delta t = 0.002$ s.